Project Report: Biosignatures in chemosynthetic and photosynthetic systems

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Project Progress

Our investigation focuses on two areas:

1. Production of volatile and stable organic biosignatures in photosynthetic ecosystems.

We conducted a field expedition to Guerrero Negro, Mexico , to collect intertidal and subtidal hypersaline microbial mats, as analogs for Earth's early microbial communities. The mats are being maintained in a greenhouse facility under quasi in situ conditions. We have constructed a theoretical model predicting flows of substrate, and harvesting of energy, by various microbial guilds within the mat community. These models predict substantial production of volatile fatty acids and hydrogen, which have now been demonstrated experimentally. We have documented the diversity of Archaea within subtidal mats, with a particular emphasis on production of methane (as a volatile product of metabolism in photosynthetic systems). Detailed work has identified a novel methanogen in this system, and has documented the depth–dependence of methane production. We have identified an isoprenoid lipid that may serve as a biomarker characteristic of hypersaline environments. This isoprenoid is hypothesized to be a diagenetic precursor of a widespread biomarker found in ancient oils. In collaboration with University of Colorado investigators, we documented the diversity of bacterial, archeal, and eukaryal domains within the subtidal mat system. This work expands the known division–level diversity of bacteria by about 40%, and has identified a novel eukaryote that branches at the kingdom level.

2. Viability of microbial communities in ophiolite–hosted alkaline springs (as possible analogs for early terrestrial or Martian habitats).

We identified and characterized a series of spring systems hosted in northern California ophiolites. Samples from Complexion Spring were prepared in thin

section and mineralogy was characterized via electron microscopy and ion microprobe analysis. These samples were found to consist of approximately one–half primary olivine mineralogy and one–half secondary alteration (i.e., serpentine) minerals, suggesting that serpentinization (to yield the potenial biological substrate, H_2), is active at the relatively low temperatures encountered by this ophiolite during its history, but that the process is not complete even after more than 100 Myr.

Highlights

- We identified a novel isoprenoid lipid that may serve as a biomarker specific to hypersaline systems. This lipid is believed to be a diagenetic precursor of a widely utilized biomarker in ancient oils.
- Our University of Colorado collaborators documented the immense microbial diversity within the subtidal hypersaline microbial mats we study. These results expand the known division–level diversity of bacteria by 40%, and have identified a novel eukaryote branching at the kingdom level.
- We documented serpentinization, a process capable of delivering H_2 to early terrestrial or Martian microbial ecosystems, in relatively low–temperature northern California ophiolite sequences.

Roadmap Objectives

- ***Objective No. 2.1:*** Mars exploration
- ***Objective No. 4.1:*** Earth's early biosphere
- ***Objective No. 5.1:*** Environment–dependent, molecular evolution in microorganisms
- ***Objective No. 5.2:*** Co–evolution of microbial communities
- ***Objective No. 6.1:*** Environmental changes and the cycling of elements by the biota, communities, and ecosystems
- ***Objective No. 7.1:*** Biosignatures to be sought in Solar System materials
- ***Objective No. 7.2:*** Biosignatures to be sought in nearby planetary systems

Mission Involvement

*Mission Class**	*Mission Name (for class 1 or 2) OR Concept (for class 3)*	*Type of Involvement***
1	MER 2003	Science Team Member
1	MRO 2005 CRISM Spectrometer	Science Team Member
2	Venus/SAGE	Instrument/Payload Development
2	MSL 2009	Instrument/Payload Development
2	Copernicus	

		Instrument/Payload Development
2	Comet Odyssey	Instrument/Payload Development
3	Astrobiology and Solar System Exploration	Other

* Mission Class: Select 1 of 3 Mission Class types below to classify your project:
1. Now flying OR Funded & in development (e.g., Mars Odyssey, MER 2003, Kepler)
2. Named mission under study / in development, but not yet funded (e.g., TPF, Mars Lander 2009)
3. Long–lead future mission / societal issues (e.g., far–future Mars or Europa, biomarkers, life definition)

** Type of Involvement = Role / Relationship with Mission
Specify one (or more) of the following: PI, Co–I, Science Team member, planning support, data analysis, background research, instrument/payload development, research or analysis techniques, other (specify).

This investigation is designed to provide science background and interpretive capacity for Mars in situ and sample return missions, as well as for telescopic life detection (e.g., TPF). By focusing on the production of mineral biosignatures in environments analogous to possible early Martian systems, and on the production of volatile biosignatures in photosynthetic ecosystems, these studies will provide an enhanced scientific context for the eventual return of data from Mars and TPF missions.

Field Expeditions

Field Trip Name: AMASE 2003	
Start Date: 8–12–2003	***End Date:*** 8–23–2004
Continent: Europe	***Country:*** Norway
State/Province: Spitzbergen	***Nearest City/Town:*** Longyearben
Latitude: 79N	***Longitude:*** 11E
Name of site(cave, mine, e.g.):	***Keywords:***
Description of Work: Geological and biological sampling at a variety of warm springs and volcanic outcroppings in the Norwegian high arctic	
Members Involved:	

Field Trip Name: Yellowstone 2003

Start Date: 9–3–2003	***End Date:*** 9–10–2003
Continent: North America	***Country:*** USA
State/Province: Wyoming	***Nearest City/Town:*** West Yellowstone, MT
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.):	***Keywords:***

Description of Work: Chemical and biological sampling from a variety of hot springs.

Members Involved:

Field Trip Name: Baja Spring 2004

Start Date: 4–22–2004	***End Date:*** 4–27–2004
Continent: North America	***Country:*** Mexico
State/Province: Baja California Sur	***Nearest City/Town:*** Guerrero Negro
Latitude: N 27 Degrees 40 minutes	***Longitude:*** W 113 degrees 55 minutes
Name of site(cave, mine, e.g.):	***Keywords:*** microbial mats

Description of Work: Sampling microbial mats for maintenance in rooftop greenhouse facilities.

Members Involved:

Field Trip Name: Ophiolite Project

Start Date: 5–10–2004	***End Date:*** 5–14–2004
Continent: North America	***Country:*** USA
State/Province: California	***Nearest City/Town:*** Castella
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.): cold spring	***Keywords:***

Description of Work: Scouting and measurement of springs issuing from ophiolite terranes.

Members Involved:

Field Trip Name: Ophiolite Project

Start Date: 8–2003	***End Date:*** 8–2003
Continent: North America	***Country:*** USA
State/Province: California	***Nearest City/Town:*** Clear Lake
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.): cold spring	***Keywords:***
Description of Work: Scouting and measurement of springs issuing from ophiolite terranes.	
Members Involved:	

Field Trip Name: Ophiolite Project

Start Date: 12–2003	***End Date:*** 12–2003
Continent: North America	***Country:*** USA
State/Province: California	***Nearest City/Town:*** Stonyford
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.): cold spring	***Keywords:***
Description of Work: Scouting and measurement of springs issuing from ophiolite terranes.	
Members Involved:	

Field Trip Name: Ophiolite Project

Start Date: 2–2004	***End Date:*** 2–2004
Continent: North America	***Country:*** USA
State/Province: California	***Nearest City/Town:*** Stonyford
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.): cold spring	***Keywords:***
Description of Work: Scouting and measurement of springs issuing from ophiolite terranes.	
Members Involved:	